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Agroforestry, food and nutritional security

Background paper for the International Conference on Forests for Food Security and Nutrition

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Key points

- Agroforestry supports food and nutritional security through the direct provision of food, by raising farmers' incomes and providing fuel for cooking, and through various ecosystem services. Agroforestry is an important climate-smart agriculture approach.
- Challenges for agroforestry in supporting food and nutritional security include policy and market constraints and underinvestment in research, but opportunities exist to promote a multifunctional agricultural approach.
- Developments in agroforestry policies are required to reform tree and land tenure for the benefit of small-scale farmers, to reform how smallholders obtain agroforestry inputs such as tree-planting material, and to recognize agroforestry as an important investment option.
- Research should support tree domestication to improve yields and enhance the complementarity and stability of food production in smallholder agroforestry systems.

1. Introduction

Agroforestry – the integration of trees with annual crop cultivation, livestock production and other farm activities – is a series of land management approaches practised by more than 1.2 billion people worldwide. Integration increases farm productivity when the various components occupy complementary niches and their associations are managed effectively (Steffan-Dewenter *et al*., 2007). Agroforestry systems may range from open parkland assemblages, to dense imitations of tropical rainforests such as home gardens, to planted mixtures of only a few species, to trees planted in hedges or on boundaries of fields and farms, with differing levels of human management of the various components. Agroforestry systems provide a variety of products and services that are important locally, nationally and globally, but their role is not always acknowledged adequately in development policies and practices, possibly reflecting the difficult-to-measure, diverse pathways by which they affect peoples' lives. Relatively low-input agroforestry options are often favoured by women who are unable to afford high-cost technologies due to severe cash and credit constraints.

Here, we assess the role of agroforestry in supporting food and nutritional security. The next section discusses this role in terms of providing food directly; incomes to support access to food; fuel for cooking; and ecosystem services related to food security. Many of the examples presented are from sub-Saharan Africa, where nine of the 20 nations with the highest burden of child under-nutrition worldwide are found (Bryce *et al*., 2008). We relate the current challenges that agroforestry faces in supporting food and nutritional security and discuss opportunities for action to improve the situation. Table 1 illustrates the extensive range of agroforestry trees that can be involved in supporting local peoples' food and nutritional security. For a more complete overview, this paper should be considered in parallel with the background paper on the contribution of forests to sustainable diets; earlier summaries of the topic should also not be neglected (e.g. Arnold, 1990; Hoskins, 1990).

Table 1. The number of tree species in the Agroforestree Database mentioned as providing tree functions of importance to smallholders for promoting food and nutritional security, and the known distribution of these species in three regions of the tropics

	Region#			
Function*	Africa	South America	Southeast Asia	Total (regions)
Human food	295 (54)	119 (43)	225 (49)	639 (50)
Animal fodder	295 (55)	96 (45)	191 (47)	582 (50)
Soil improvement	194 (51)	73 (45)	154 (45)	421 (48)
Fuel	357 (53)	126 (42)	249 (47)	732 (49)
Total (functions)	1 141 (53)	414 (43)	819 (47)	2 374 (49)

Note: The percentage of references to indigenous species is given in brackets. Data are stratified by 'human food' (fruits, nuts, etc., for direct consumption), 'animal fodder' (important for dairy, meat production, etc.), 'soil improvement' (important to support staple crop yields), all of which are related directly or indirectly to food production (see section on agroforestry for food production), and 'fuel', which relates to the provision of charcoal, fuelwood, etc., for the proper processing and cooking of food (see section on agroforestry, fuel and food). Based on the number of mentions summed across functions compared with the total number of species (650) in the database, it is evident that many tree species perform several functions. The data illustrate that smallholders are able to use a wide range of both indigenous and exotic trees, in approximately equal proportions overall, for products and services supporting food and nutritional security.

* The Agroforestree Database is an open-access database maintained by ICRAF (www.worldagroforestry.org/resources/databases/agroforestree) that contains data on a wide range of products and services provided by trees that are of interest to farming communities in the tropics; information on a subset of four functions is given here. Data are presented on the number of species given in the database as used for a particular purpose that can be found in particular geographic regions.

The Agroforestree Database contains global data on species distributions, summarized here into regions according to en.wikipedia.org/wiki/List_of_sovereign_states_and_dependent_territories_by_continent for Africa and South America, and www.nationsonline.org/oneworld/asia.htm for Southeast Asia. A factor determining the greater number of total references to the African continent is the focus given to documenting species found there.

2. The benefits of agroforestry systems for food and nutritional security

Agroforestry for food production

Solving the problem of food and nutritional security requires among other interventions a range of interconnected agricultural approaches, including improvements in staple crop productivity, the bio-fortification of staples, and the cultivation of a wider range of edible plants that provide fruits, nuts, vegetables, etc., for more diverse diets (Frison *et al*., 2011). Potential for the diversification of crop production lies in the great range of lesser-used indigenous foods found in forests and wooded lands that are often richer in micronutrients, fibre and protein than staple crops (see background paper on the contribution of forests to sustainable diets; Malézieux, 2013). Although such foods have traditionally been harvested from forests and woodlands, access to these resources is declining (FAO, 2010). In this context, cultivation provides an alternative resource. Moreover, the yield and quality of production can be improved if attention is given to genetic improvement and farm management methods, making planting an attractive option (for many wild trees, a two-fold yield improvement or more is possible through genetic selection; Jamnadass *et al*., 2011).

When bringing trees from the wild into cultivation it is essential to increase yields: if indigenous trees are perceived as relatively unproductive, agriculture in deforested areas is likely to be dominated by staple crops, and agrobiodiversity will be reduced (Sunderland, 2011). Some food-providing trees and palms, especially fruit-producing ones, have been managed by people in a transition from the wild to cultivation in farmland for millennia, resulting in complex agroforestry systems that contain many different foods; for other tree foods, the move to domestication is much more recent and is based on scientific inquiry (Torquebiau, 1984; Clement, 2004). A combination of indigenous and exotic tree foods in agroforestry systems supports nutrition, the stability of production, and farmer income (see Box 1 for an African example). Mixtures of fruit trees that spread production provide a year-round supply of important nutrients (Figure 1).

Box 1. Developing domestic markets for tree foods: the case of smallholder fruit production in sub-Saharan Africa

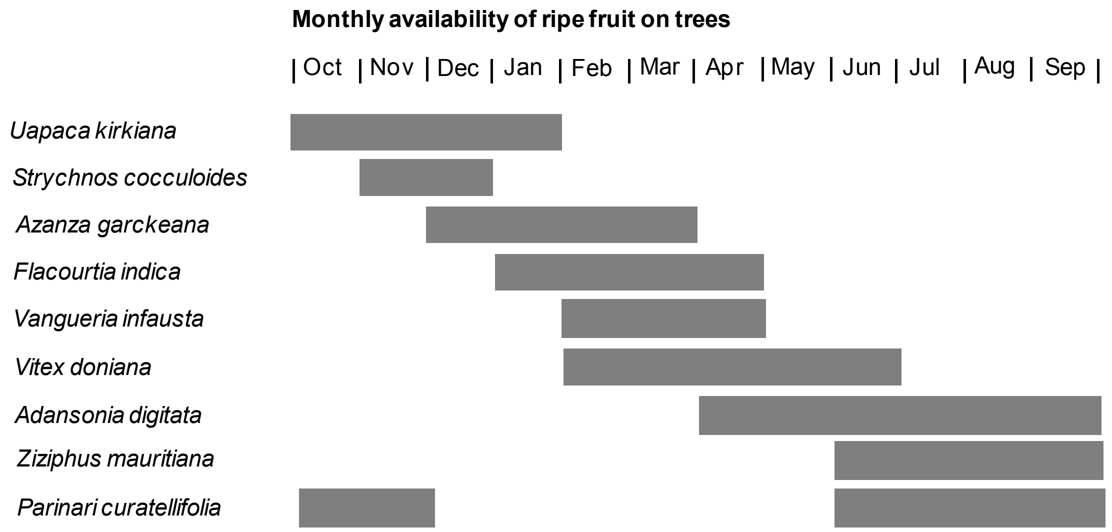
Exotic and indigenous fruits cultivated and managed in agroforestry systems are important foods in Africa, as illustrated by household surveys. In Kenya, for example, a 2004 survey of more than 900 households found that over 90 percent grew fruits, with at least one-quarter growing banana (*Musa* spp.), avocado (*Persea americana*) and mango (*Mangifera indica*). Over two-thirds of households that reported fruit production harvested from at least four fruit species, while over half sold some fruit. Similarly, in a 2009 survey of more than 1 100 rural households in Malawi, at least half consumed mango and/or papaya (*Carica papaya*) and one-third consumed oranges (*Citrus sinensis*), among other fruits, most of which were harvested from their own farms.

Despite this, the average consumption of fruit and vegetables in sub-Saharan Africa is significantly lower than the minimum recommended daily intake of 400 g per person. One reason for this is that poor households that have to buy food understandably focus on the purchase of staples such as maize and rice that provide relatively cheap and 'concentrated' sources of carbohydrate to meet basic energy needs, leaving only a small fraction of the family budget to spend on other foods. Expenditure analysis shows, however, that as incomes increase the purchase of fruit also increases, meaning that as incomes grow in the region due to economic development, domestic markets for fruit are predicted to grow by about 5 percent per year over the next ten years, when human population increases and urbanization are also taken into consideration. If production and delivery to consumers can be made more efficient, the potential for farmers to boost their incomes by meeting this demand is high. Women farmers in particular can benefit, since the harvesting and processing of fruit are often seen as activities that fit within their domains. The incomes women receive are more likely to be used to purchase other foods for household consumption than incomes received by men. As fruit production becomes more commercially profitable, however, businesses may be taken over by men.

One opportunity to influence child nutrition in sub-Saharan Africa is through home-grown school feeding programmes that link schools with local agricultural producers to promote more diverse, nutritionally balanced diets. Another is to supply the rapidly developing supermarket sector in the region through the development of farmer producer groups that can negotiate with retailers and meet their quantity requirements and quality standards.

Source: adapted from Jamnadass *et al*. (2011).

Figure 1. A fruit tree 'portfolio' consisting of nine tree species fruiting at different times of the year, based on indigenous fruits in Malawi



At least one species in the portfolio is ripe every month, including over traditional periods of hunger due to lulls in the production of staple crops (around January and February in Malawi). Based on the vitamin C content of the fruit of these trees and the recommended daily dietary intake, around 50 percent of the vitamin C needs of an adult man could be met by the daily consumption of 100 g of fruit pulp of one of two species, azanza (*Azanza garckeana*) or bush orange (*Strychnos cocculoides*), for the period November to March, with only 25 g daily of the highly vitamin C rich baobab (*Adansonia digitata*) fruit pulp providing the requirement for the rest of the year (excluding October). Knowing the vitamin contents and phenologies of different fruits allows them to be combined appropriately in cultivation. Other ways to help spread fruit production are to cultivate late- and early-fruiting varieties of a particular tree species and/or apply to only some trees management options such as pruning or coppicing that delay production. Source: modified from Jamnadass *et al*. (2011).

As well as directly providing edible products, agroforestry trees support food production by a range of other means, including by providing shade and support for crops that need it, supporting animal production and improving soil fertility. Agroforestry has an important role in increasing the yields of vegetables that, with fruit, provide varied and nutritionally balanced diets rather than calories alone (Susila *et al*., 2012). Trees can modify the microclimate for garden crops under harsh climate and support climbing plants such as yam (Maliki *et al*., 2012). In an initiative in East Africa, more than 200 000 smallholder dairy farmers are growing fodder shrubs as supplementary feed. The typical increase in milk yield achieved by farmers is enabling them to raise extra revenue from milk sales of more than US$100 per cow per year, and allowing them to provide more milk to urban consumers (Place *et al*., 2009).

An analysis of more than 90 peer-reviewed studies on soil fertility improvement found consistent evidence of benefits in maize yields in Africa from planting nitrogen-fixing green fertilizers, including trees and shrubs, although the level of response varied by soil type and technology (Sileshi *et al*., 2008). As well as increasing average yields, the planting of trees as green fertilizers in southern Africa is able to stabilize crop production in drought years and during other extreme weather events, and improve crop rain use efficiency (Sileshi *et al*., 2011, 2012) (Box 2 and Figure 2). This is important for food security in the context of climate change, which is increasing drought incidence in the region.

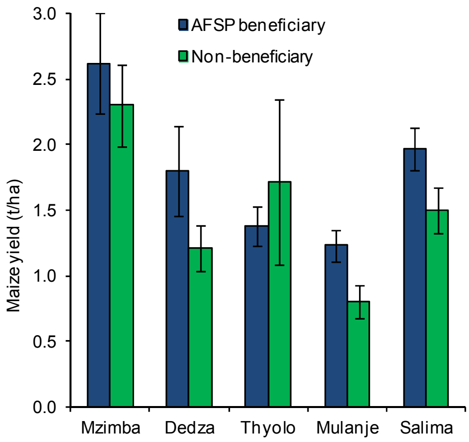
Supporting the regeneration of natural vegetation in agroforestry systems can also provide significant benefits for staple crop yields. Farmer-managed natural regeneration (FMNR) of faidherbia (*Faidherbia albida*) and other leguminous trees in dryland agroforests (parklands) in semi-arid and sub-humid Africa is a good example. Since 1985, FMNR has been encouraged in Niger by a policy shift that awarded tree tenure to farmers (as well as by more favourable wetter weather); it has led to the 're-greening' of approximately 5 million hectares (Sendzimir *et al.*, 2011). FMNR in the Sahel has led to improvements in sorghum and millet yields, and positive relationships have been observed with dietary diversity and household income (Place and Binam, 2013).

Box 2. The Malawi Agroforestry Food Security Programme, household food security and dietary diversity

Farmers in Malawi have recognized that low soil fertility is a major constraint on their ability to produce food. To address this through the planting of leguminous tree and shrubs, ICRAF and partners, with funding from Irish Aid, implemented the Malawi Agroforestry Food Security Programme, which between 2007 and 2011 reached about 180 000 farmers. An external review of the programme in five districts surveyed 283 households that were beneficiaries (participants in the programme) and 200 that were not. In four of the five districts, maize yields were on average higher for beneficiaries than for non-beneficiaries (see Figure 2); on average, beneficiaries also had more food-secure months per year. Except in one district, dietary diversity (measured as the number of different types of food group consumed in a day) was also higher for beneficiaries, which could be attributed to the greater own use of fruit trees whose management and use (of existing trees) and planting were also promoted by the project, as well as to increases in incomes from farm sales for food purchases. The use of improved green fertiliser technologies has relevance beyond Malawi and the southern Africa region, and efforts to scale up appropriate methods are underway in other parts of Africa and beyond.

Source: adapted from CEI (2011).

Figure 2. Maize yields in five districts in Malawi with and without the intervention of the Agroforestry Food Security Programme, based on 283 beneficiaries and 200 non-beneficiaries distributed across districts



Note: bars represent 95 percent confidence intervals; in three cases (Dedza, Mulanje and Salima) the difference between categories is statistically significant (see Box 2 for further information).

Agroforestry for incomes to support access to food

Examples from Africa of widely traded agroforestry tree foods that support farmer incomes and the food security of rural and urban populations include the indigenous semi-domesticated and widely cultivated fruit safou (*Dacryodes edulis*; Schreckenberg *et al.*, 2006), the indigenous incipient domesticate shea nut (*Vitellaria paradoxa*; Masters and Addaquay, 2011) and exotic mango. New commercial markets for fruits are developing in Africa as a result of recent investments by Coca Cola, Del Monte and others to source produce locally for juice manufacture. The production of timber and other agroforestry tree products for markets, as well as other farm produce (e.g. staples), the yields of which are increased in agroforestry systems (see previous section), also supports incomes for food purchase. Many trees are cultivated to provide medicines from bark, leaves, roots, etc., which are sold to support incomes and are used for self treatment, supporting the health of communities (Muriuki *et al*., 2012).

Market data recorded for agroforestry tree products are sparse, but information on export value is quantified for tree commodity crops such as palm oil (derived from oil palm, *Elaeis guineensis*), coffee (primarily from *Coffea arabica*), rubber (from *Hevea brasiliensis*), cocoa (from cacao, *Theobroma cacao*) and tea (primarily from *Camellia sinensis*). Each of these is grown to a significant extent by smallholders, as illustrated in Indonesia, where, in 2011, small farms were estimated to contribute 42, 96, 85, 94 and 46 percent of the country's total production area for palm oil, coffee, rubber, cocoa and tea, respectively (Government of Indonesia, 2013). Unlike Indonesia, many countries do not formally differentiate between smallholder and plantation production, but more than two-thirds of coffee produced worldwide is estimated to be from smallholdings (International Coffee Organization, 2013), while the figure is 90 percent for cocoa (International Cocoa Organization, 2013).

Taken together, the annual export value of the above five commodities is tens of billions of United States dollars (FAO, 2013a). Less clear is the proportion of value that accrues to smallholder producers, but often production constitutes a considerable proportion of farm takings and is used to support household food purchases. There is a danger, however, that the planting of commodities will result in the conversion of natural forest – which contains important local foods – to agricultural land and a risk that food crops will be displaced from farmland in a trend towards the growing of monocultures (e.g. oil palm; Danielsen *et al*., 2009). Buying food using the income received from a single commodity crop can also lead to food insecurity for farm households when payments are one-off, delayed or unpredictable in value. Monocultures also reduce resilience to shocks such as drought, flood and, often (although not always), the outbreak of pests and diseases. As a result, tree commodity crops are often viewed sceptically within agricultural production-based strategies designed to improve nutrition (FAO, 2012); for some farmers, though, incomes from tree commodity crops provide an important way to obtain sufficient food when their farms are too small to cultivate enough food to meet their needs (Arnold, 1990).

Mixed agroforestry regimes can help to avoid many of the negative effects described above by combining tree commodities in diverse production systems with locally important food trees, staple crops, vegetables and edible fungi – such as shade coffee and shade cocoa systems (Jagoret *et al*., 2011, 2012; Sustainable Cocoa Initiative, 2013) – which increase or at least do not decrease commodity yields and profitability (Clough *et al*., 2011). Such systems have often been traditionally practised but are now being actively encouraged through certification and other schemes by some international purchasers of tree commodity crops (Millard, 2011). There are also opportunities to develop valuable new tree commodities (Box 3). Not all tree commodities are however amenable to production in diversified systems (e.g. oil palm is not well suited; Donald, 2004).

Box 3. Integrating markets and cultivation to support the sustainable development of a new tree commodity crop: the case of allanblackia

The seed of allanblackia (*Allanblackia* spp.), found wild in the humid forests of Central, East and West Africa, yield edible oil with a significant potential of more than 100 000 tonnes annually in the global food market, especially as a 'hardstock' for the production of healthy spreads that are low in trans-fats. A private–public partnership known as Novella Africa is developing a sustainable allanblackia oil business that could be worth hundreds of millions of United States dollars annually for local farmers. A supply chain for seed has been established in Ghana, Nigeria and the United Republic of Tanzania based on harvesting by local communities in natural forests and from trees remaining in farmland after forest clearance. Currently, volumes are small (hundreds of tonnes) and oil is being exported for food product development. At the same time, the tree is being brought into cultivation by improving seed handling and developing vegetative propagation methods, and through the selection of superior genotypes. Tens of thousands of seedlings and clones have so far been distributed to smallholders. The integration of allanblackia into small-scale cocoa farms is being promoted to support more biodiverse and resilient agricultural landscapes. As allanblackia trees grow, cocoa trees provide the shade they need; when they are grown, they in turn will act as shade for cocoa. Cocoa and allanblackia provide harvests at different times of the year and – when the allanblackia trees have matured – will spread farmers' incomes.

Source: adapted from Jamnadass *et al*. (2010).

Agroforestry, fuel and food

Traditional energy sources have received little attention in current energy debates, but fuelwood and charcoal from trees are crucial for the survival and well-being of perhaps two billion people, enabling them to cook food to make it safe for consumption and palatable and to release the energy within it (FAO, 2008). In sub-Saharan Africa, the use of charcoal and fuelwood is still increasing rapidly; the value of the charcoal industry there was approximately US$8 billion in 2007 (World Bank, 2011). The fuelwood and charcoal industries are therefore important for food and nutritional security, because they both produce energy and generate income; with the increasing prices of 'modern' energy sources, this is likely to remain so for some time.

In poor households, fuelwood and charcoal are often burnt in open fires or poorly functioning stoves, with substantial emissions of pollutants (especially from fuelwood) that damage human health and may lead to the deaths of more than one million people annually worldwide, the majority women (Bailis *et al*., 2005). Fuel quality depends on the tree species being burnt, with poor families often using species that were traditionally avoided because of their harmful smoke or that were maintained for other products, such as fruit (Brouwer *et al*., 1997).

Reduced access and increased prices of wood-based biomass have led to initiatives to promote agroforestry cultivation. Where agroforestry is practised by smallholders, less fuelwood needs to be purchased, there is less reliance on collecting from natural stands and less time is involved in collection. This leaves more time for income-generating activities, especially for women, who are usually the major fuelwood collectors (Thorlakson and Neufeldt, 2012). Access to cooking fuel provides people with more flexibility in what they can eat, including foods with better nutritional profiles that require more energy to cook. The cultivation of woodlots allows the production of wood that is less harmful when burnt and has higher energy content. The use of better stoves – with greater efficiency – reduces greenhouse gas emissions relative to the energy generated for cooking purposes.

Agroforestry, ecosystem services, climate change and food

Agroforestry trees provide important ecosystem services, including soil, spring, stream and watershed protection, animal and plant biodiversity conservation, and carbon sequestration and storage, all of which ultimately affect food and nutritional security (Garrity, 2004). Individual farmers can be encouraged to preserve and reinforce these functions, which extend beyond their farms, by payments for ecosystem services, but more important in determining their behaviour is the direct products and services they receive from trees (Roshetko *et al*., 2007a). An advantage of smallholder agroforestry systems is that they can perform wider services while directly supporting production (Leakey, 2010).

Appropriate combinations of crops, animals and trees in agroforestry systems can not only increase farm yields, they can promote ecological and social resilience to change because the various components of a system, and the interactions between them, will respond in differing ways to disturbances. A diversity of species and functions within integrated production systems is therefore a risk reduction strategy, and agroforestry is recognized as an important component in climate-smart agriculture for both its adaptation and mitigation roles. For example, soil fertility improvement technologies can stabilize crop yields in drought conditions (see above). In Niger, farmers explain that increasing the number of tree species per function insures them against 'function failure' in their farming systems because at least some species will provide each required function, even in the driest years (Faye *et al*., 2011). In western Kenya, subsistence farmers practising agroforestry (e.g. for soil erosion control, improving soil fertility and fuelwood provision) identify more coping strategies when exposed to climate-related hazards than those who do not (Thorlakson and Neufeldt, 2012).

Kristjanson *et al.* (2012) explored the relationship between food security and farmer innovation in the context of changing circumstances, including climate variability, with farmers in Ethiopia, Kenya, Uganda and the United Republic of Tanzania. A strong positive relationship was demonstrated between food security and the adoption of new farming practices, although it was not possible to determine whether this was because innovative households are more food-secure as a result of innovation, or if more food-secure households are better placed to subsequently innovate. Many of the 700 surveyed households were practising agroforestry, but generally they were only planting small numbers of trees, suggesting that there is a need to understand why there has not been wider uptake of agroforestry. Possibly, the initial investment required before benefits are received from trees is an important factor.

A diversity of trees in farmland and neighbouring natural forest fragments, where present, supports populations of pollinator species such as insects and birds that are essential for many crops (Garibaldi *et al*., 2013). Many fruit tree species that are important as human foods rely on insect pollinators for their production (Klein *et al*., 2007), while diverse farms that provide an alternative habitat for pollinator communities can support the regeneration of food plants in neighbouring forest (Hagen and Kraemer, 2010).

3. Challenges for agroforestry in supporting food and nutritional security

Policy constraints

Policy plays an important role in distinguishing countries and regions that have benefited from agroforestry from those that have not. Place *et al*. (2012) considered that there are three key policy areas in which constraints need to be overcome in order for agroforestry benefits to be distributed more widely. First, farmers need land and tree tenure. Where these are absent or contested, farmer involvement in tree-planting and management can be limited, but when they are assured, greater interest in agroforestry is stimulated (e.g. the previously cited case of FMNR in Niger). Land tenure rights are particularly important for agroforestry compared with other agricultural practices because of the relatively long period that may be required to realise benefits. Sometimes, policies on ownership have perverse effects, for example when regulations designed to control the harvesting, cutting or sale of tree products from forests are applied to farmland and limit the ability to use planted trees as substitutes for a wild resource.

Second, policies that determine how farmers obtain seeds, seedlings and clones of a wide range of tree species suitable for their various planting requirements are crucial (Lillesø *et al*., 2011). Current policies often slow the adoption of agroforestry, for example by discriminating against small-scale entrepreneurial seed and seedling suppliers by providing NGOs and government extension services with funds to give free seeds to farmers. Although well-intentioned (to protect intellectual property, stop the introduction of potentially invasive species, etc.), laws to control germplasm flows internationally have also slowed smallholder access to appropriate planting material by, for example, limiting the transfer to Africa of superior cultivars of fruit trees developed in Asia.

Third, the current policy environment often does not recognize agroforestry options as an attractive investment area in agriculture. For example, governments often subsidize the provision of artificial fertilizers to enhance staple crop yields, which discourages the adoption of improved fallow technologies that could ultimately increase staple crop production more cost effectively and sustainably. Another problem is the lack of attention given to tree products and services in data collection and therefore there is a lack of information on the value of agroforestry trees in supporting food and nutritional security (FAO, 2013b).

Constraints in delivering tree products to markets

For many tree products, markets are poorly structured and coordinated (Roshetko *et al*., 2007b). This results in low and unstable returns to farmers and high prices for buyers of tree foods, which limits their consumption. Problems often cited by producers include the absence of a collective bargaining system, poor transport infrastructure, and the involvement of multiple intermediaries in the supply chain, all of which act to reduce farm prices. For perishable goods such as fruit, the result is also high wastage along the supply chain and a failure to reach quality grades. Prevailing low returns mean that farmers struggle to afford inputs to improve their suboptimal farm management practices. Traders also face many problems, such as poor roads, corrupt officials and the high cost of collecting from geographically scattered producers.

Underinvestment in research

There has been underinvestment in the development of new tree lines, cultivars, etc., that have high yields and provide quality products under smallholder production conditions. Until recently, for example, scientists mostly ignored the great potential for the improvement of indigenous fruit trees (Jamnadass *et al*., 2011). There are insufficient numbers of scientists working on bringing these indigenous species into cultivation in the tropics. For many indigenous food trees, only limited information is available on nutritional value, which can be expected to vary significantly even within species.

Although the benefits of agroforestry systems for responding to climate change are recognized, the great diversity of agroforestry landscapes and the sometimes long life cycles of trees and production systems mean that the most effective combinations of trees, staple crops, vegetables, animals, etc., and how to manage them together in particular environments, are often unknown (Neufeldt *et al*., 2012). A significant gap in knowledge is the effects of climate change on interactions between pollinators and plants in agroforestry systems. Asynchronies between tree-pollinator life cycles introduced by climate change could be particularly problematic for the yields of fruit trees, which otherwise constitute an important means to address malnutrition in the context of climate change.

4. Options to increase the role of agroforestry in supporting food and nutritional security

Policy opportunities

Guidelines were revised recently for policymakers to support agroforestry (FAO, 2013b), which recommend, for example: reforming unfavourable regulations, legal restrictions and restrictive financial mechanisms that inhibit the practice of agroforestry; clarifying land-use policy goals and regulations; elaborating new policies that acknowledge the role of trees on farms in development; and strengthening farmer access to markets for tree products. CIRAD, CATIE and ICRAF have joined FAO to support national policy reforms on this basis.

Several countries, such as Brazil, are developing or refreshing their agroforestry strategies in a participatory way with local communities, while the governments of China and India have embarked on ambitious programmes to increase tree cover outside forests. Some governments are setting minimum requirements for tree cover on farms. In Kenya, where a minimum of 10 percent cover has been set, the government has allocated funds to assist farmers to meet this requirement. Agroforestry is recognized under the United Nations Framework Convention on Climate Change as a key mitigation method within agriculture, and national climate change adaptation plans need to further embrace agroforestry as a climate-smart agricultural response.

A three-step approach for agroforestry to support food and nutritional security

Leakey (2010) described a step-wise multifunctional agricultural approach by which agroforestry can further support food and nutritional security: support for soil fertility replenishment technologies (discussed above) is followed by participatory tree domestication (Box 4) and then by entrepreneurship and value-addition to tree products. Potential interventions to benefit local communities in enterprise development include value chain analysis, as undertaken, for example, by TechnoServe[1] to improve banana markets in East Africa, where multiple brokerage levels deprived farmers of significant revenues (Milder, 2008). Based on the TechnoServe analysis, smallholders were organized into producer business groups linked directly to wholesale banana buyers, which resulted in an increase in farmer income of over 80 percent. In the context of food and nutritional security, 'nutrient-sensitive' value chains are required, which means improving nutritional knowledge and awareness among value-chain actors and consumers, focusing on promoting the involvement of women, and considering markets for a wider range of tree foods. By promoting tree food processing and other value additions, the non-farm rural economy can also be stimulated.

[1] www.technoserve.org.

Box 4. The participatory tree domestication approach in Cameroon: description and impacts

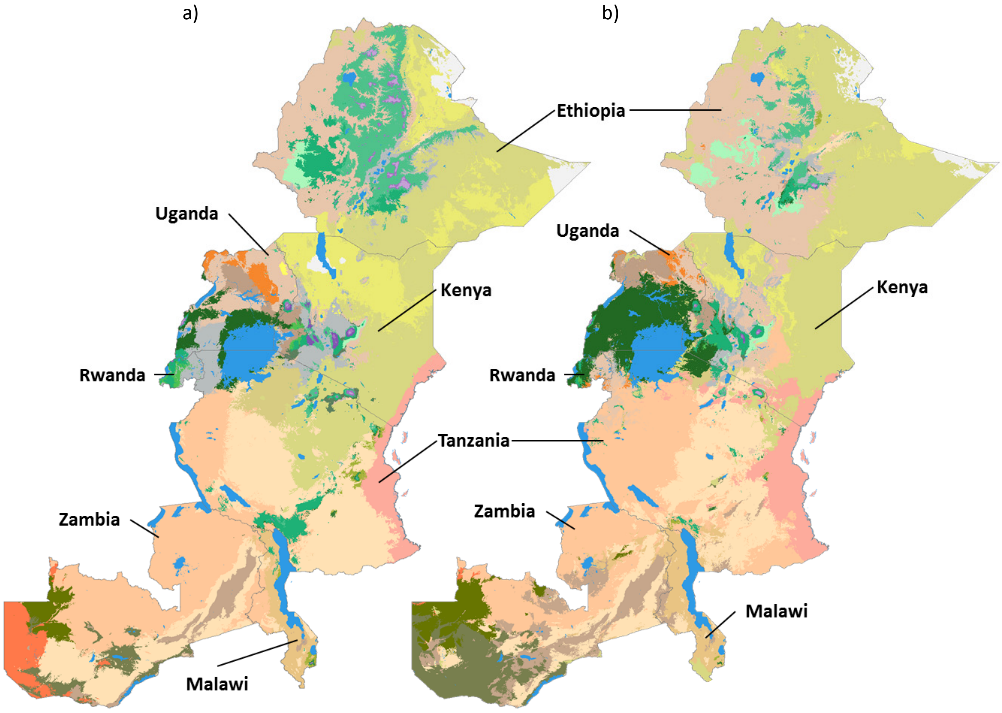
A new way of domesticating trees, referred to in the literature as the participatory approach, has been developed in Cameroon in the last decade as a close collaboration between scientists and farmers. The approach involves combining scientific advances in knowledge with local communities' experiences to bring a range of valuable indigenous fruit tree species into cultivation. An important aspect is using vegetative propagation methods to reduce the time to maturity and provide fruit more quickly to farmers. When applied in Cameroon, significant impacts have been achieved with the method. More fruit has been observed in farmers' diets for approximately 50 percent of adopters, and farm cropping systems have become more diverse. Smallholder incomes have increased from the sales of fruits and fruit tree nursery stock (for planting by other farmers), and there has been a reduction in human migration from rural to urban areas because young people have stayed in villages to engage in new farming activities. The approach is being extended through the development of rural resource centres that train farmers in how to propagate and manage trees, and provide fruit processing facilities and business training. Centres act as venues for farmers to meet and form associations that allow them to market their products and obtain services more effectively.

Adapted from Tchoundjeu *et al*. (2010).

Planning for climate change

One way in which agroforestry practices can be adapted to climate change is by adjusting the tree composition of systems to take account of new conditions (Dawson *et al*., 2011). Changes in composition can be made at the interspecific and intraspecific levels, the latter making use of within-species variations in growth in differing conditions. At the species level, the selection of 'generalist' species that grow well under varied conditions may be an important response, although this could result in a few highly adaptable exotics becoming dominant, which would be undesirable in providing a wide range of products and services. Another approach to planning for the future is to develop vegetation maps and explore how these will change under different climate scenarios (Figure 3); the best sites for planting particular tree species can be planned accordingly. At the intraspecific level, trials are required to measure genetic variation in climate-related traits, as was carried our recently by the SAFRUIT initiative on Sahelian fruit trees that are important to local people in the region (SAFRUIT, 2013).

Figure 3. Vegetation maps for East Africa, showing the current baseline (a) and predicted vegetation (b) at 2080 under change scenario A1B (model CCCMA-CGCM31)



Note: Each vegetation type is assigned a specific colour (see www.vegetationmap4africa.org/). Maps suggest significant shifts in the suitability domains for tree species. Plans for agroforestry planting can take this into account.

5. Recommendations

To increase the role of agroforestry in food and nutritional security, we recommend the following:

- The current role of agroforestry tree products and services in supporting the food and nutritional security of the rural poor in different production systems should be better quantified. Where possible, this should be done separately for men, women and children, small-scale farmers, the landless poor and local traders. This will allow options for intervention to be better targeted.

- The development of agroforestry policy should not be confined to the agricultural or forest sectors; it needs a place of its own. Required reforms include targeting tree and land tenure and how farmers obtain the trees they plant, and the recognition of agroforestry as an investment option.

- Research should support tree domestication appropriate for smallholders' needs and assess complementarity and resilience in agroforestry systems under climate change, in the context of other global challenges to food and nutritional security.

Acknowledgements

We thank colleagues Jonathan Cornelius, Roger Leakey, Henry Neufeldt, Jim Roshetko, Hesti Tata and Barbara Vinceti for providing information during the compilation of this paper, as well as Flordeliza Bassiag, Timo Beiermann, Marie-Eve Ciparisse, Zakayo Kimuge, Gunasingham Mikunthan, Sisay Nune, Jimena Rábago Aguilar, Benjamin De Ridder, Noemi Stadler-Kaulich, Jennifer Schulz and other members of the Community for Climate Change Mitigation in Agriculture.

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